



VEECO MS-40
PORTABLE AUTOMATIC LEAK DETECTOR
Operations and Maintenance
Manual

CHAPTER ONE

General Information

1.1 Introduction

This Operations & Maintenance Manual describes in detail the information needed to understand the operation and functions of the Veeco MS-40 Fully Automatic Portable Leak Detector (illustrated in Figure 1-1), and provides the information needed to service and maintain the unit in optimal working condition. This manual has been divided into five chapters:

- Chapter 1 General Information
- Chapter 2 Operating the MS-40
- Chapter 3 Theory of Operation
- Chapter 4 Service & Maintenance
- Chapter 5 Parts Lists

Chapter 1, General Information, describes the features of the MS-40 Leak Detector, its basic operation, unpacking and inspection of the unit, installation requirements as well as specifications for the unit.

Chapter 2, Operating the MS-40, details the controls necessary to operate the MS-40, both during normal operation of the unit as well as when placed in its Service Mode. All external connectors and their applicability to the unit and its functions are also discussed. This chapter also includes an explanation of what occurs during the unit's start-up procedure, a description of the leak test modes, an explanation of sniff testing procedures, a step-by-step description of how to perform actual leak testing, operations involving the optional external pump, an explanation of what occurs during the unit's shutdown procedure, the setting of the unit's testing parameters, and MS-40 self-testing procedures.

Chapter 3, Theory of Operation, has been included in order to give the MS-40 user information on how the unit functions. Maintenance personnel servicing the unit will find this most useful, since a thorough technical understanding of how the unit operates is critical when performing the repairs and service discussed in the following chapter.



Figure 1-1
Veeco MS-40 Portable Automatic Leak Detector

Chapter 4, Service & Maintenance, describes in further detail the unit's Service Mode, the necessary tuning/calibration procedures for the MS-40, required periodic service procedures and recommended service intervals, detection and correction of contamination within the vacuum system, procedures for venting the vacuum system, cleaning requirements and procedures, calibration of measurement components, valve block service and repair, repair/replacement of the unit's electronics and a full listing of front panel error codes, their probable causes and our recommended corrective actions.

Chapter 5, MS-40 Parts Lists, contains a full list of recommended spare parts and a complete listing of the spare parts available from Veeco.

This manual provides the specific documentation needed to operate and service the MS-40 Leak Detector. The MS-40 System is a highly technical system that incorporates many sophisticated technologies. In view of this, every effort has been made to automate both the unit's operation and maintenance procedures. It is imperative, however, that operations and service personnel familiarize themselves with the operations and maintenance procedures in this manual in order to maximize the efficiency of the unit, as well as minimize downtime caused by improper service and repair.

1.2 Unpacking & Inspection

The MS-40 is shipped in a specially constructed package that minimizes the possibility of damage during transit. The shipping carton and packing materials should be saved for future use. Note that a Bill of Material is packed within the carton indicating all of the items shipped with the unit.

Prior to unpacking the unit, inspect the exterior carton for any signs of damage. After unpacking the unit, inspect the leak detector itself for any obvious damage. If damage to the unit should be found, a claim should be filed immediately with the shipping carrier and a copy of that claim must also be forwarded to Veeco Instruments. Should the MS-40 fail to function as required, or fail to meet its specifications, contact the Customer Service Department at Veeco (Veeco Instruments, Terminal Drive, Plainview, NY 11803; tel: (516) 349-8300/fax (516) 349-8321) or your local representative. Please note that Veeco Instruments must be contacted prior to the return of any damaged equipment.

Once the leak detector has been removed from its package, the MS-40 must be opened and all shipping material removed from the unit's internal roughing and turbomolecular pumps. To access the internal roughing pump, the front panel must be opened; to access the turbomolecular pump, the back panel must be

opened. Both panels are hinged at the bottom and held with a single screw at the top of each panel. To open a panel, loosen the captive screw at the top of the panel (a 1/4 turn is sufficient to unloosen the screw) and gently lower the door. Make sure that the surface the unit is placed on a flat surface (Veeco Cart, P/N 0137-705-00, recommended). Remove all shipping materials and tie-down wraps from the internal pumps.

The MS-40 is shipped without oil in the internal roughing pump, which must be filled prior to use. In addition, to protect the pump during shipment, it is fitted with two blanks that cover its intake and filter connections. Remove these blanks and attach the flex hosing and filter (refer to Figure 1-2 for a diagram illustrating the proper installation for the hose and filter connections) with the provided centering rings and clamps. Also, the unit's purge tubing (refer to Figure 1-2) is fitted with a 1/4" ferrule blank. Unscrew the blank and reattach the tubing as indicated in Figure 1-2.

Parts List for Figure 1-2:

ILLUSTRATION #	PART NUMBER	DESCRIPTION
1	1660-236-00 (60 Hz.) 1660-236-01 (50 Hz.)	Rotary Vane Mechanical Pump
2	1621-173-00 1621-183-00	Polyflow Cap, 1/4" Ferrule Nut
3		Polyflow Tubing, Purge Line
4		Blank Cap
5	1621-231-12	KF16 Centering Ring
6	1621-239-02	KF16 Clamp
7	0137-205-00	Manifold, Roughing Pump
8		Blank Cap
9	1621-231-12	KF16 Centering Ring
10	1621-239-02	KF16 Clamp
11	1680-055-00	Exhaust Filter KF16 to 1/4 NPT Adaptor

To fill the pump with oil, unscrew the black cap to the right of the exhaust filter. Using the oil (1990-900-01) and the funnel (1331-191-00) provided in the installation kit, slowly fill the pump until the level in the sight glass is approximately 1/4" below the fill line. Replace the black oil fill cap.

When all shipping material has been removed, all pump connections have been made, and the pump has been filled with oil, replace the right side panel and close the front and rear doors.

NOTE:

The MS-40 Leak Detector is factory tested and calibrated prior to shipment and once installed, is ready for use.

If the internal pump fails to come on when power is applied to the MS-40, make sure that the pump power switch is in the "ON" position. The ON/OFF switch for the internal pump is located on the rear of the pump motor.

An **Installation Kit** (Veeco P/N 0137-800-00) is included with the unit when it is shipped. The kit contains:

<u>Part Number</u>	<u>Description</u>
1680-055-00	Exhaust Filter
0103-141-01	Filament Kit (box of 5)
1331-191-00	Funnel
1330-391-00	7/64 Allen Wrench
1990-900-01	VMP-19 Oil (1 liter)
0137-807-00	Kit, Cart Mounting
0137-804-00	N2 Kit
1621-224-02	Adaptor, KF16 to 1/4" NPT
1621-227-05	QC Adaptor, KF25 to 1 1/8"
0126-284-00	Blank Plug, 1/18
1620-731-00	Elbow, 1/4 NPT to 3/8 Tube
1750-054-00	Tubing, Tygon, 1/4"

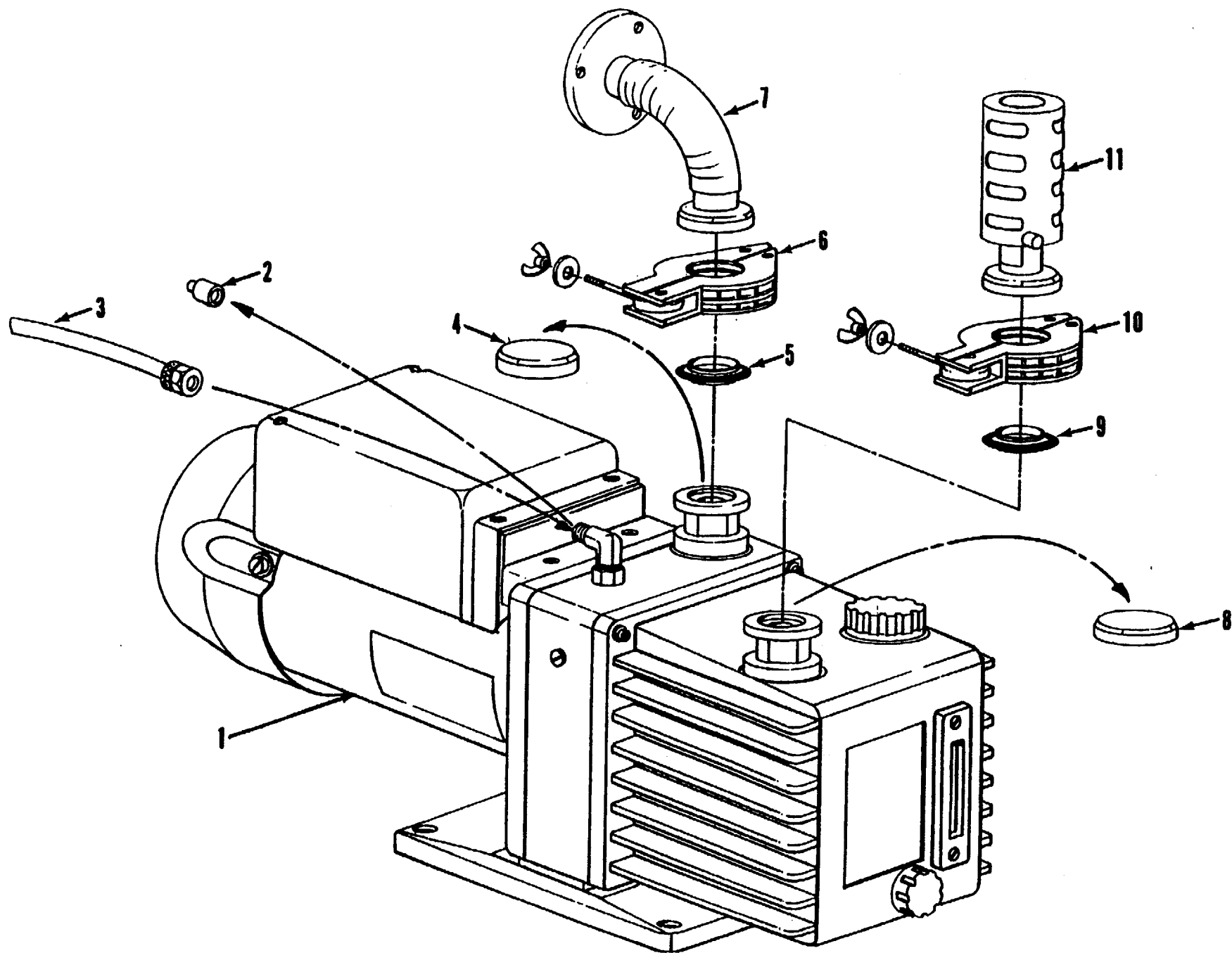


Figure 1-2
MS-40 Internal Rotary Vane Mechanical Pump

1.3 Installation

The MS-40 has been designed as a completely self-contained portable leak detector and therefore has the capability to work in a wide range of environments. However, before installation in a work area, certain requirements must be met.

- A properly grounded electrical supply (115V/60Hz/8A, 230-240V/50Hz/4A, 100V/50Hz/8A, or 100V/60Hz/8A as labelled on rear of unit) must be available for the unit.
- A user supplied helium supply is usually necessary for the unit (but not for all testing, e.g., sealed parts should already be pre-bombed with helium). The MS-40 can use either a Mass 3 or Mass 4 helium supply. Virtually any standard purity helium may be used during leak testing. Depending on the type of leak testing that will be performed, a spray probe (for vacuum testing), a sniffer assembly (for sniff testing) or a test cup (for pressure bombing testing) will be necessary. All of these items are available directly from Veeco Instruments.
- The recommended ambient temperature range for the unit is from 10°C to 40°C. Also, excessively humid environments should be avoided.
- Depending upon the immediate environment, an external exhaust facility may be necessary. A bulkhead is installed on the rear of the MS-40 that is intended for user-provided 3/8" polyflow tubing. Note that the bulkhead is not connected to the internal exhaust filter of the unit but must be connected by the User. The tubing is then attached to a functional exhaust system.

WARNING!

Only qualified service personnel should operate the unit when either the front or rear panels are open. Potentially lethal high voltages are continually applied to the circuit boards and other areas within the unit during its operation. Although these areas are shielded and well marked, failure to follow this precaution may possibly lead to severe injury or death.

1.4 Features & Specifications

FEATURES

Sensitivity:	4×10^{-11} std cc/sec air equivalent
Leak Rate Range:	10×10^0 to 4×10^{-11} std cc/sec air equivalent (with optional external pump) 10×10^{-4} to 4×10^{-11} std cc/sec air equivalent (without external pump)
Start-Up:	Fully functional in less than 3 minutes: consists of: turbomolecular pump acceleration, a complete set of self-diagnostics, turning on filament, checking and assuring hi-vac status, measuring system offsets and measuring background helium
Internal Calibrator:	Helium 4, 1×10^{-8} to 3×10^{-8} std cc/sec air equivalent with integral solenoid valve
Testable Masses:	Helium Mass 3 or 4
Tuning:	Automatic
Calibration:	Automatic for Helium 4 using an internal calibrator of 1×10^{-8} to 3×10^{-8} std cc/sec air equivalent
Auto Zero:	Automatic zeroing of leak rate while in test mode initiated by pressing the ZERO pushbutton
Background Compensation:	Continuous automatic compensation for system back ground
Remote Control Unit:	Molded A.B.S. plastic laminate over tactile membrane switch array Controls similar to User Panel
RS-232C Port:	Two standard bidirectional ports. One port dedicated to the remote control unit. The second port is dedicated to data transfer to an external computer or control module.

Ranging:
[Automatic/Standard
Mode]

Without an external roughing pump, begins at the least sensitive gross range (10^{-4}). The unit ranges downward until a leak is detected or until it reaches its most sensitive range (10^{-10}). With the optional external pump, if a gross leak is detected, the unit ranges up to the appropriate decade. If a gross leak is not detected, the unit ranges downward until a leak is detected or until it reaches its most sensitive range.

Ranging:
[Manual Mode]

May operate at any range, selectable by the operator. The 10^0 to 10^{-3} range is only available when the optional external pump has been installed.

Measurement Units:

Pressure: milli Torr or millibar (selectable with a switch located underneath the Service Panel accessible when the unit's front panel has been opened)

Leak Rate: std cc/sec (standard cubic centimeters/second) or mbar l/sec (millibar liters/second)

PUMPS

Mechanical Pump: Internal 3 cfm dual stage rotary vane pump

Turbo Pump: 52 liter/second turbomolecular pump

External Pump: Optional 7 or 16 cfm dual stage rotary vane (mechanical) pump

PERFORMANCE SPECIFICATIONS

Sensitivity: 4×10^{-11} std cc/sec air equivalent (direct mode)
 4×10^{-10} std cc/sec air equivalent (reverse mode)

Resolution: 14 at Mass 4

Response Time: Reverse Mode < 3 seconds
Fine Mode < 2 seconds

Test Time: <1.5 seconds on a blank port to a pre-selected range in the reverse flow test mode

Noise & Drift:	<4% on 10^{-10} range
Testable Masses:	3 and 4
Maximum Measurable Leak:	10 x 10^{-4} std cc/sec air equivalent (without external pump) 10 std cc/sec air equivalent (with optional external pump)
Maximum Inlet Pressure:	Gross Mode: Atm (with optional external pump) Reverse Mode: 7.5 Torr Direct Mode: 100 mTorr
Test Mode Leak	Gross: 10 to 1 x 10^{-3} std cc/sec helium Intermediate (Reverse): 10 x 10^{-4} to 6 x 10^{-10} Fine (Direct): 10 x 10^{-9} to 6 x 10^{-11}

ELECTRONICS & USER INTERFACE

System Controller:	Microprocessor based; four integrated boards used: A controls the unit's computer, logic and sensors B controls the unit's mass spectrometer voltage supplies C controls the unit's displays and controls D controls the unit's handheld remote <i>Display:</i> Green LED alphanumeric and bar graph displays <i>Data Input:</i> Through dedicated function keys
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MISCELLANEOUS

Power Requirements:	115V, 60Hz, 8 Amp 230-240V, 50Hz, 4 Amp 100V, 50Hz, 8 Amp 100V, 60Hz, 8 Amp
Dimensions:	15.5"H x 20.5"W x 14.25"D
Weight:	87 lbs.

1.5 General Description

The MS-40 is a fully automatic, dual mode, turbomolecular pumped portable leak detector. Each of its two modes (Reverse Flow or Direct Flow) is automatically selected by the leak detector based on the currently selected leak rate range.

Reverse Flow Mode permits rapid testing for leaks in test objects that are characterized by a high degree of outgassing. Testing can start at test port pressures of Atm for leaks from 10 to 1×10^{-3} std cc/sec (Gross Mode testing) when using the optional external pump or pressures of 7.5 Torr for leaks between 10×10^{-4} and 6×10^{-10} std cc/sec (Intermediate Mode testing) for units not equipped with an external pump.

Direct Flow Mode is most useful for testing objects that demand clean testing and higher sensitivity. In this mode, the leak detector measures leaks from 10×10^{-9} to 6×10^{-11} std cc/sec, at a test port pressure of 100 milliTorr or less. However, this mode is also capable of determining larger leaks. Once the unit is in this mode and a larger leak has been detected, the unit will range back to the appropriate decade.

The MS-40 uses two types of automatic testing: an automatic test mode with automatic ranging and an automatic test mode with manual ranging. In automatic ranging mode, the leak detector automatically ranges downward (to more sensitive leak rate ranges) until a leak is found. When using manual ranging, the operator of the leak detector controls the range in which a particular test object is tested.

In the Automatic Test Mode, when using Automatic Ranging, all the functions of the leak detector, including the evacuation (pump down) of the test object and the functions of all pumps and valves are controlled by the MS-40 computer. Additionally, all measurements and display information about the leak rate and system performance are under the control of the computer.

The Automatic Test Mode, when using Manual Ranging, is identical to the Automatic Testing/Automatic Ranging mode except that the User preselects the range (e.g., 10^{-5} std cc/sec) for testing. If a measured leak is either above or below the preselected decade, the leak detector operator can manually range the unit either up or down. The remainder of the testing procedure is handled by the MS-40 computer in exactly the same manner as with the Automatic Ranging Mode.

1.5.1 Standard Operation

This is the normal operating mode for the MS-40. During operation, the User need only use the right (uncovered) portion of the display panel (the User Panel is illustrated in Figure 2-1). All functions to be accessed and display information needed to leak test an object are found on this panel. The panel displays bar graphs indicating test port pressure and leak rate values. Additionally, the panel indicates the current leak range mode, an accept/reject indicator that indicates if the leak being tested is above or below the test set point, and whether the unit is in test or standby mode. The user panel also has toggles for automatic or manual ranging (including greater/lesser pushbuttons), audio volume pushbuttons, an auto-zero pushbutton, a sniff mode indicator and START and VENT pushbuttons (START is used to commence the testing cycle as well as to interrupt the testing cycle without the chance of accidentally venting the system, while VENT is used to interrupt testing and/or to vent the test port).

1.5.2 Service Mode

WARNING!

The Service Mode of the MS-40 is intended for use by qualified Veeco Instruments personnel or Users specifically trained by Veeco Instruments. Under no circumstances should any individual be assigned access to this mode without a complete knowledge of vacuum systems as well as the MS-40 System. Use by an unqualified operator may result in damage to the unit and/or personal injury.

Service Mode is initiated by first opening the rear panel of the unit (loosen the 1/4-turn screw at the top of the panel, then gently lower the door) and then pressing the black toggle button at the top right hand side of the circuit board that is attached to the panel. Once the toggle has been pressed, the unit is placed in Service Mode and the Service Mode indicator is illuminated.

Service Mode disables the automatic valve controls and allows the User to manually control all of the valves within the vacuum system. The valves are controlled by a cluster of labeled momentary switches located on the left of the User Panel. The LED indicator on each switch is lit when the valve is open. Included within the vacuum system are: the auto-calibrator valve, external rough valve, fine (direct) valve, foreline (reverse) valve, gross testing valve, purge valve, roughing valve, sniffer valve and the vent valve.

Grouped to the right of the Service Mode Indicator are a series of LED indicators. The Service Mode allows the setting of the unit's Amplifier Gain, Anode Voltage, Calibration Temperature and Internal Calibration Value in conjunction with the arrow buttons and LED alphanumeric display to the right of the indicators. Additionally, the user may view the unit's calibration temperature, the emission current of the filament within the unit's spectrometer, the error code present (indicating a possible fault within the unit - if present), the current supplied to the filament in the mass spectrometer, the calibration standard (e.g., 2×10^{-8} std cc/sec @ 24°C) of the internal calibrator, the leak rate of the test object (a numeric value the same leak rate as displayed by the bar graph on the User Panel), the pressure measured at the test port and the total number of hours the unit has been in operation.

Below the indicators and to the right of the valve controls are two sets of momentary switches. In either Standard or Service Modes, they allow the User to turn on/off the filament within the mass spectrometer, choose between two different filaments within the spectrometer, and perform an actual test on the calibrator or optimize the mass spectrometer. When strictly in Service Mode, the User is also able to choose between either a helium or air standard for leak rate measurement or choose whether the MS-40 will measure either with Mass 3 or 4 helium.

2.3 Starting the MS-40 Leak Detector

The MS-40 is started from the User Panel simply by pressing the ON/OFF (I/O) switch. During the three-minute Start-up mode, the following will occur within the unit:

- 1 The unit will activate a self-diagnostic routine.
- 2 The foreline area will be pumped down.
- 3 The turbomolecular pump will spin up to its rated speed.
- 4 If the filament was on when the unit was last turned off, the filament will be on again at the end of the start-up mode. If the filament was off when the unit was turned off, the user will have to press the FIL ON momentary switch to turn on the filament.

NOTE:

During the start up procedure, all LED's on the User Panel will be tested by being sequentially lit.

When the Start-up mode has been completed, the Automatic Ranging indicator will be lit, the test port measurement gauge will be activated, the User Panel numeric display will indicate 4 and the READY light indicator will be lit.

Pre-Testing Start-Up Procedure:

Ensure that all connections are secure and all utilities are available. Check that:

- A.C. power is connected.
- A helium supply source is ready and available (when applicable).
- There is a sufficient supply of oil in both the internal and external rough pumps
- All external accessories are properly connected.

2.4 Leak Testing

Leak testing is most often performed on the MS-40 by connecting a test object to the leak detector test port. The unit's leak detector test port is located on the top right of the MS-40's housing.

Vacuum Testing:

Through the use of the detector's internal rough pump (and external rough pump, if so equipped) the test object is evacuated. Once accomplished, the area of the test object suspected to have a leak is sprayed with helium gas. As the helium (and other gases) pass through a hole in the test object and are collected by the unit:

- 1 The gases entering the unit are ionized (positively charged)
- 2 Helium molecules are separated from all other gas molecules
- 3 Helium ions will then strike the collector plate causing an electron flow equivalent to a minute current, which is measured and amplified so that the measurement of the leak is displayed on the User/Service Panel.

An alternate commonly used method is to test an object pre-filled with helium gas. The test object is placed in a test chamber which is evacuated and tested (as above). The MS-40 subsequently displays the measurement of the leak on the User/Service Panel.

The procedure for leak testing an object in the MS-40 (without an external pump connected) is as follows :

- 1 Connect the test object to the test port located at the top of the MS-40.
- 2 Press the green START pushbutton.
- 3 The rough valve immediately opens. Gases are evacuated from the test object (the object is pumped down).
- 4 When the test port pressure reaches Crossover 1 (7.5 Torr maximum), the reverse/foreline valve opens.

- 5 If a vacuum testing procedure is underway, spraying of the test object with helium should now commence.
- 6 Leak testing begins in the 10^{-4} std cc/sec range.
- 7 The unit will continue to search for a leak, ranging downward until it reaches the 10^{-9} std cc/sec range.
- 8 If a leak is still not found, the unit will automatically begin fine (direct) testing. The rough valve will close, the fine valve will open and the leak detector will range downward to the 10^{-10} std cc/sec range. If the test port pressure is above Crossover 2, the unit will return to a roughing state, then will again test when Crossover has been reached.
- 9 If a leak is not found, the unit will continue to test at this level until the VENT pushbutton is pressed. If a leak is found, the unit will range upward to the proper range. The unit stays in direct mode when ranging upward until it reaches the 10^{-4} range, where it crosses back into reverse mode testing.
- 10 When leak testing has been completed, pressing and holding the VENT pushbutton (the default is for 0.5 second or may be programmed by the user - the D3 time interval) closes all vacuum system valves except for the foreline valve, opens the vent valve and vents the test port and test object.

2.5 Operation With an External Pump

- 1 Connect the test object to the test port.
- 2 Press the green START pushbutton.
- 3 The external rough valve immediately opens. Gases are evacuated from the test object (the object is pumped down).
- 4 As soon as roughing has commenced, the gross valve opens.
- 5 Leak testing begins in the 10^{-4} std cc/sec range.
- 6 If a vacuum testing procedure is underway, spraying of the test object with helium should now commence.
- 7 If a gross leak is detected the unit will range up to the appropriate decade, while the test object continues to be pumped down.
- 8 If no leak is found and the test port pressure has reached Crossover 1, the unit will begin intermediate (reverse mode) testing. The external rough valve and gross valve will close, the internal rough valve will open and the leak detector will range downward from the 10^{-4} std cc/sec range to the 10^{-9} std cc/sec range.
- 9 If again a leak is not found and the test port pressure has reached programmed Crossover 2 pressure, the internal rough valve closes, the fine valve opens and the unit ranges to the 10^{-10} std cc/sec range.
- 10 The unit will continue to test at this level unless a leak is found or until the VENT pushbutton is pressed.
- 11 When leak testing has been completed, pressing and holding the VENT pushbutton (the default is for 0.5 second or may be programmed by the user - the D3 time interval) closes all vacuum system valves except for the foreline valve, opens the vent valve and vents the test port and test object.

Calibration (Cal)

The Calibration function is activated by pressing the CAL momentary switch.

The Calibration function of the leak detector is available only after the Cal-Check procedure has been completed. After the Cal-Check cycle is completed, when the actual leak rate measured by the unit is close to, but not exactly the same as the internal leak rate standard, the Calibration function may be used. Since the Calibration function adjusts the amplifier gain, once initiated, the leak check of the Cal-Check function will now conform to the internal leak rate standard. Note that consistent differences greater than 15% may indicate an improperly tuned mass spectrometer or a fault within the unit.

Tune

Pressing the TUNE momentary switch initiates an automatic tuning cycle. During the tuning cycle, voltages applied to the mass spectrometer are adjusted and optimized for peak sensitivity and performance. It is recommended that the Tune function be used in conjunction with the Cal-Check function. Since the Calibration function basically increases or decreases the measurement gain of the unit, without the optimization of the Tune function, the unit eventually may not be able to self-calibrate.

CHAPTER THREE

Theory Of Operation

3.1 Introduction: Leak Detection Theory

When designing and manufacturing systems that contain gases or fluids, or systems that are normally evacuated, the manufacturer or tester must take into account the degree of leakage that can occur. To qualify these products, various methods may be selected to test these products for leaks. The amount of actual leakage that can be tolerated is different for every application and therefore must be determined from the conditions of the application itself. From this data the manufacturer will be able to establish the limits of maximum permissible leakage standards and will also be able to determine the maximum permissible pressure levels within a product or system under actual working conditions. Further, the manufacturer will need the ability to discover and localize any leaks in the product or system tested. In all cases, the maximum allowable leak rate, as well as the testing methods and procedures, should be specified before a product or system is manufactured.

Many commercial, industrial and military products and processes require hermetic sealing. In general, these products include equipment exposed to pressures above or below those of its immediate environment, vacuum equipment used in the manufacture of semiconductors and related research, and items produced for industrial and commercial applications, most notably the refrigeration and automotive industries. Hermetic tightness (sealing) is narrowly defined as the absence of leakage, however, no manufactured object can be considered leak tight. Statements such as "no detectable leaks" or "zero leakage" are not valid specifications for acceptance testing. Even in the absence of defect within a product or system, gas will always permeate through metal, crystals, polymers and glasses. Therefore, "leak tightness" is only a relative term.

The degree of permissible leakage depends on how and where the product or system is to be used, the amount of the object's content (liquid or gas) that is permitted to escape over a certain time period, or the amount of external atmosphere or liquid that is permitted to penetrate the object over a certain time period. The size of the permissible leak is defined as part of the performance requirements of the product or system. Leak standards are set for the following reasons:

- To prevent the loss of contained gases or liquids
- To prevent hazards caused by escaping toxic materials
- To prevent contamination due to materials leaking from or leaking into an object
- To test the projected reliability of sealed systems or the components within the systems.

When setting the limits of allowable leakage, it is always necessary to set a practical leakage level for the product under testing. Decreasing the permissible leak rate below a practical level and increasing the sensitivity of the required test method only brings with it an unnecessary increase in the time required and the cost of performing a test.

Leak testing is divided into two general categories, **Leak Measurement** and **Leak Location**.

Leak Measurement is the quantified assessment of an object's or system's leak rate and is also the preferred method of determining that a leak does exist. **Leak Location** is the procedure of pinpointing the precise location of individual leaks. When testing an object, the most reliable sequence is to first measure the total leakage of a test object, then, if necessary, determine the location of individual leaks.

A leak rate specification should take into account the effect of leakage on the system and its application. Long term storage of the object or system may be necessary and should be considered when creating a leakage standard.

Any leak detection procedure requires careful planning. Ample consideration to test sensitivity and response time is required when testing any object. At times, it may be preferable to specify a maximum tolerable leakage rather than specifying a maximum allowable leak rate. The maximum tolerable leak rate may be calculated by multiplying the maximum allowable leak rate by the length of time a system or object is expected to be used (including storage time). If a gas or liquid is not introduced to the system or object until it becomes operational (at some future date), the maximum tolerable leakage need be only specified for the duration of its operation. The level of the maximum tolerable leakage should always be specified when the total amount of leakage is more important than the leak rate.

A commonly used method for determining the maximum allowable leak rate is derived from the consideration of leaks in the following situations:

- System failure during the operational life of the system
- Hazards to personnel and equipment when leaks occur
- Unacceptable appearance of the system
- Assurance of proper design and construction of the manufactured equipment.

When considering these four factors, when determining system specifications, the smallest leak rate will be the maximum allowable leak rate. If the content of the test object is liquid, it is necessary to correlate the maximum liquid leak rate to the leak rate of helium. Once the maximum leak rate of the liquid in the test object has been calculated, it is very simple to conduct an accurate leak test for an object designed to contain liquid, since a calibrated helium gas standard is an integral part of the MS-40.

Of all the instruments and devices used for leak detection, helium-sensitive mass spectrometer based leak detectors such as the MS-40 have been proven to be by far the most sensitive and accurate. Further, this type of unit is generally easily calibrated, does not require operator judgement to be used effectively, and most importantly, is not destructive or harmful to test personnel or the tested object.

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The remainder of this chapter describes in detail the operation of the MS-40 portable leak detector. It is divided into a discussion of direct and reverse flow modes, a functional description of the leak detector and a description of the major components and their functions within the MS-40.

3.2 Direct Flow & Reverse Flow Modes

The MS-40 is capable of detecting leaks in three separate ranges: gross mode range, intermediate mode range and fine mode range. The gross and intermediate modes use a form of detection known as "Reverse Flow" while the fine mode uses a form of detection known as "Direct Flow." All flow modes are controlled directly and automatically by the MS-40's computer.

Reverse Flow:

The Reverse Flow Mode is particularly useful for detecting and measuring leaks in test objects that have a high degree of outgassing or when a fast crossover at a high test port pressure is desired. In this mode, testing for "Gross" leaks is accomplished by connecting the external roughing pump to the vacuum system, opening the external rough valve, the foreline valve and the gross valve. All other valves are closed. The test port is connected to the foreline of the turbomolecular pump through a restriction. This allows the sample helium to back-diffuse through the pump. When testing in reverse mode, the foreline pressure is usually in the 10^{-3} Torr range or greater, the turbomolecular pump actually acts as a buffer against pressure bursts into the high vacuum region (the area containing the mass spectrometer). Therefore, crossover can occur at much higher pressures in reverse flow mode than in direct flow mode. For the MS-40, the Gross Mode Leak Range is defined as 10×10^0 to 1×10^{-3} std cc/sec.

Without an external pump, Gross Mode is not available. If the unit is unable to pump down the test object to a sufficient level to begin testing in the unit's "intermediate" or reverse flow mode, actual leak testing will not begin. The unit will remain in its roughing state until the operator cancels the test cycle. Since the maximum crossover for the MS-40 is quite high, this may be an indication that the test object has a very large leak.

The unit's intermediate mode also uses Reverse Flow Mode testing. When the test port pressure reaches the pre-designated "crossover" setpoint (9.6 Torr maximum) the unit will "crossover" to "intermediate mode" testing (the actual point of crossover may be set by the system operator). At crossover, the foreline valve opens, the internal rough valve remains open, while all other valves are closed. Gases from the test object are introduced into the foreline of the turbomolecular pump, and "back-diffuse" through the pump. As in gross mode testing, the turbomolecular pump acts as a buffer against pressure bursts into the high vacuum region

(the area containing the mass spectrometer). For the MS-40, the Intermediate Mode Leak Range is defined as 10×10^{-4} to 6×10^{-10} std cc/sec.

Direct Flow:

The Direct Flow Mode is suited for testing parts that have a leak rate specification less than 6×10^{-10} std cc/sec, or when testing objects that are clean, dry and cannot tolerate exposure to backstreaming of molecular oil during testing. In this mode, the test object is directly connected to the high vacuum section and therefore the mass spectrometer. This allows for much higher sensitivity and ultra-clean testing in comparison with the reverse flow mode, but requires a much lower crossover pressure.

In the MS-40 direct flow mode testing is also known as Fine Mode testing. During Fine Mode testing, the fine valve and foreline valves are open. All other valves are closed. Crossover takes place when the test port is at approximately 500 milliTorr or less (adjustable by the system operator). The fine mode test leak range is between 10×10^{-5} to 4×10^{-11} std cc/sec.

NOTE

Once the MS-40 has crossed over into its direct flow mode, and needs to range upward, it will stay in this mode until it reaches the top of the 10-5 range.

3.3 Functional Description of Operation

The MS-40 Portable is a helium based mass spectrometer leak detector that may be used for both quantifying and locating leaks in objects that can be evacuated or pressurized. Helium that is present in a test object is drawn into the unit (either through the test port or through the sniffer valve), isolated and detected by a mass spectrometer, and converted into an electric signal. The electric signal generated is proportional to the leak rate of the helium drawn through the leak found in the test object. Once this signal is amplified, the signal is displayed as a leak rate on the User Panel of the MS-40.

Helium is used as a tracer gas because of its unique combination of properties:

- Helium is present in the atmosphere at a rate of only 5 parts per million, therefore it is unusual to find a high atmospheric background of helium that may disrupt testing
- Helium is neither explosive nor toxic it is completely inert and will not contaminate a test object
- Helium does not contaminate or desensitize its own detector as is common with detectors using other tracer gases
- Helium molecules are small (mass 3 or 4 helium may be used for the MS-40) and therefore flow readily through extremely small leaks.

The operation of the MS-40 is discussed below. The operator of the unit should use this information in conjunction with the unit's Vacuum Schematic (as illustrated in Figure 3-1). The description follows the sequence of a basic test cycle. A test cycle is started by connecting a test object to the test port (or by connecting the sniffer assembly to the sniffer port) and by pressing the START button.

Prior to testing ensure that the unit is in its functional READY state. The START-UP procedure is described in Section 2.3. When the unit is ready for testing, the vacuum system will have the following status:

- 1 The internal mechanical pump and the turbomolecular pump will be functioning; the external mechanical pump will also be functioning (if installed).
- 2 The foreline valve will be open; all other valves will be closed.
- 3 The "Hi-Vac" system will be fully evacuated by the turbomolecular pump.

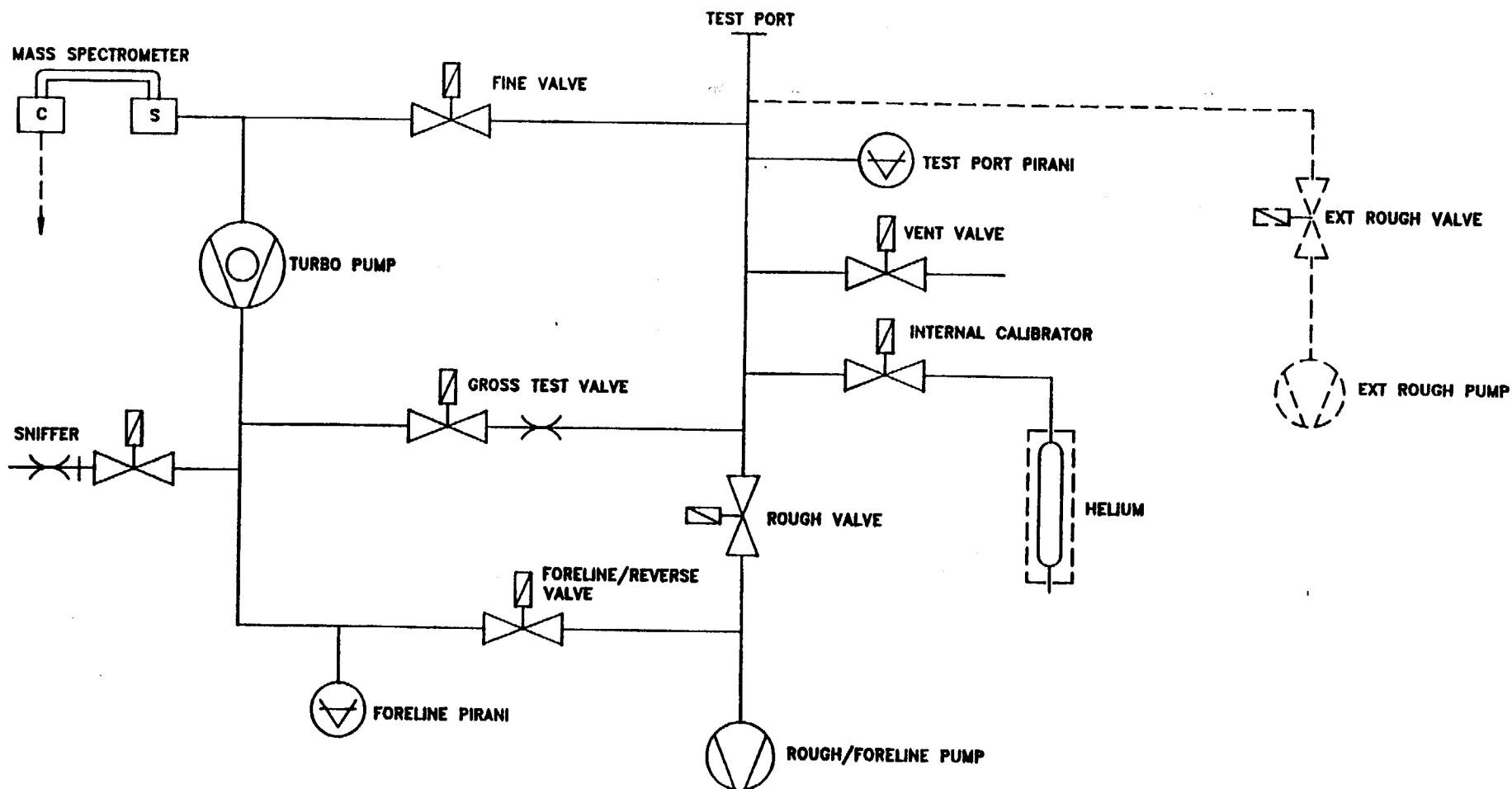


Figure 3-1
MS-40 Vacuum System Schematic Diagram

Pressing the START pushbutton opens the rough valve. The internal rotary vane mechanical pump (the roughing pump) or the external roughing pump (when equipped with the unit) will begin to evacuate the test object. The falling pressure within the test port and test object is monitored by a pirani gauge attached to the test port.

In systems without an external roughing pump, the internal mechanical pump serves as both the roughing and foreline pump. Consequently, during the roughing state, the foreline is not being serviced. Note that due to the advanced design of the MS-40 system, the turbomolecular pump has an extremely high foreline tolerance. This allows for much longer than normal roughing intervals than similar leak detectors.

The MS-40's computer monitors foreline pressure using its foreline pirani gauge. If foreline pressure reaches 1,000 milliTor, the MS-40 computer will stop the roughing cycle by closing the internal roughing valve, opening the foreline valve and servicing the foreline. When foreline pressure has been reduced to 150 milliTor, the roughing cycle is resumed.

Testing begins once the pressure at the test port reaches the pre-set crossover setpoint for the appropriate test mode.

The sample gases of the test object disperse throughout the confines of the hi-vac system. As gas molecules enter the ion source chamber of the mass spectrometer, an electrically heated filament provides a source of electrons that collide with the gas molecules and produce positively charged ions. The production of these ions is referred to as ionization. Due to the differences in mass of the ionized gases, only helium ions have the ability to traverse the two 90° magnetic sections of the spectrometer housing to the collector. It is at the collector that the ions are converted into electrical current and processed by the MS-40 computer for display on the User Panel. The MS-40 has been programmed with the ability to test using either Mass 3 or Mass 4 helium.

When the unit is equipped with an external mechanical pump, once Gross Mode operation is complete (assuming a leak has not been discovered) the unit "crosses over" into intermediate mode (reverse flow) testing. In the vacuum system the internal rough valve is opened and the foreline valve remains open. All other valves are closed. During crossover, the equalization of pressures may cause a temporary increase in foreline pressure. This increase is termed a burst. Measured by a pirani gauge in

the foreline, if the burst causes the foreline pressure to increase to over 7,000 milliTorr, the test cycle will be aborted and ERROR 05 will be posted. If a burst causes foreline pressure to increase to over 8,000 milliTorr, the filament will be turned off, all valves except the foreline will be closed, the turbo pump will be turned off, and ERROR 01 will be posted. See Error Codes in section 4.10 for further information. The crossover pressure (Crossover 1) should be adjusted by the User to provide the shortest possible test cycle duration without producing excessive pressure bursts into the foreline region of the unit. Note that since foreline tolerance is very high, the usual result of the increase of foreline pressure will be a variable background reading.

Once Intermediate Mode operation is complete, the Fine (Direct Flow) Mode testing begins. Within the vacuum system, the fine valve is opened while the rough valves close. At this point the test port is fully connected to the high-vacuum section. The equalization of the two pressures will cause a pressure burst in the high-vacuum section. If the burst is over 5×10^{-4} Torr, the mass spectrometer filament will be turned off for 10 seconds and ERROR 02 will be posted. The system will then turn the filament back on and attempt to resume testing (see Error Codes, section 4.10, for further information).

To prevent an excessive pressure burst, the test port may be evacuated for a longer period by lowering the crossover pressure (Crossover 2 - refer to Section 2.7 for information on how to adjust this parameter) or by changing the "delay" setting (refer to Section 2.7 for detailed information on delay parameters). In this case, delay refers to either delaying the opening of the fine valve (the direct gateway between the high-vacuum section and the test port) or the closing of the rough valve (allowing further evacuation of the test port/test object area). Optimizing these two parameters allows the user to shorten the test cycle while still being able to safely operate the unit.

Often the setting of delays will depend on the size of the test object. Smaller, cleaner objects will tend to produce small pressure bursts and therefore use relatively high crossover setpoints, larger, dirtier objects tend to produce larger bursts that can be prevented by extending the roughing time by delaying the onset of Fine Mode testing.

After Crossover 2 has been reached, and the unit is in the Fine testing mode, pressure in the test object continues to be reduced until it is equalized with the high-vacuum section. Concurrently, the MS-40 ranges downward to the ultimate Direct Flow sensitivity of 4×10^{-11} std cc/sec, unless a larger leak is found.

After the leak (or leaks) in the test object is/are found and quantified, the test is terminated by pressing either the VENT or START pushbuttons. The unit's computer will then close either the fine, rough or gross valve (dependent on the current testing mode). Note that once the START pushbutton is pressed, the unit is placed in its STANDBY mode (without any venting the test port). If the VENT button is depressed for a period of time (as adjusted by the User, see Section 2.7 for instructions on setting this "delay") the unit will open the vent valve. The opening of the vent valve allows the test object to be brought to atmosphere, thereby allowing it to be removed from the leak detector's test port. The duration of venting is also adjustable (again see Section 2.7 for instructions on setting the delay of the venting period). If the ambient air in the testing area has a high moisture content, it is advisable to vent the unit with dry nitrogen. Using dry nitrogen prevents water vapor from collecting in the unit, which then must be pumped out during the next testing cycle.

The MS-40 is automatically tuned and calibrated by using the factory-installed temperature compensated helium standard, traceable to NIST, as a reference. During tuning, the unit's computer controls the vacuum system's valves and adjusts the various voltages of the mass spectrometer to obtain an optimum response to the helium signal from the reference standard. After the voltages are optimized, the gain of the amplifier is adjusted until the displayed leak rate value corresponds to the temperature compensated value of the helium standard.

In the Sniff Test Mode, the sniffer port has a direct internal connection to the test port. The flow rate of the sniffed gases is limited by the size of the sniffer probe, sniffer assembly and most importantly the fixed leak in the sniffer probe.

In the event of a power failure, all valves within the vacuum system will automatically close. The mechanical pump will shut off, the turbo-

molecular pump will also shut off, however, it will take several minutes for the blades of the pump to stop spinning. When power is again available, the unit will automatically begin its normal "power-up" sequence. If, before the power failure, the filament was activated, the unit will power-up with the filament on. If the filament was off prior to power loss, the User will have to manually activate the filament (by pressing the FIL ON momentary switch located on the User Panel).

3.4 Description of Major Components

VACUUM SYSTEM

Mass Spectrometer: The mass spectrometer is the component of the vacuum system that detects the helium tracer gas present in the test object. The unit ionizes the gas molecules, separates the helium ions from other gas ions, and converts the helium ions into an electrical current that represents the size of the leak. The spectrometer consists of three parts:

- the gas to ion converter,
- the magnetic deflector assembly, and
- the ion collector.

Gas to ion converter (for ion production): To permit neutral atoms and molecules of gas to be separated by a magnetic mass spectrometer, they must first be converted to positively charged ions. Energy for this conversion is provided by the ion source. Inside of the ion source, there is an electrically heated filament that provides a source of electrons. As these electrons collide with gas molecules, they split off electrons from the gas molecules and therefore create positively charged gas ions. These ions then encounter the electrostatic fields, established within the ion source by the ion repeller, the ion chamber, the focusing plates and the object plate. The end-result of this arrangement is to accelerate the gas ions into a well defined, mono-energetic beam.

Magnetic Deflector Assembly (Ion Separation): Since the gas entering the spectrometer contains atoms and molecules of different kinds, the ion beam will likewise contain a variety of ions including nitrogen, oxygen, carbon dioxide, and, if a leak has been found, helium. Magnets are mounted on the outer portion of the spectrometer, outside of the vacuum system, and are used to create magnetic fields that are perpendicular to the beam of gas ions. A magnetic field causes the ions to deflect off their current trajectories, the amount of deflection depends upon the mass of the gas ion. Lighter ions such as hydrogen are deflected to a greater extent than heavier ions such as oxygen.

Two identical magnetic fields are used in the MS-40's mass spectrometer. The first magnetic field is organized so that only helium has the right mass to pass through the field and through the narrow opening in the baffle on the far side of the magnetic field. Most of the other ions will be deflected in a different direction (they will be either too heavy or too

light) and will be intercepted by the baffle. A few of the non-helium ions will be able to pass through the baffle (due to random scattering and bouncing of the ions within the mass spectrometer). Therefore, a second identical magnetic field and baffle is used again, which acts to virtually eliminate all ions except for helium ions. By using this construction of two separate magnets and baffles, helium is selectively transmitted to its target, while other gases, even if present in large quantities, are rejected.

Ion Collector: After the gas ions pass through the magnetic fields and baffles of the spectrometer, is a **slit plate** (a plate with a thin and narrow aperture). Behind this plate is a metal plate termed the **target**. As the helium ion strikes the target, the target becomes positively charged, causing an extremely small electron flow, as low as 1×10^{-15} Amperes. The current flow is detected and magnified by an amplifier within the collector. The first stage of amplification is within the high vacuum environment to assure stability, minimize the time constant and reduce stray "noise" pick-up. The amplified signal is proportional to the partial pressure of helium within the source. This signal, the actual leak rate, is sent to the MS-40 computer for display on the User Panel.

VALVE BLOCK ASSEMBLY

The valve block assembly consists of:

- **Calibrator Valve (with Calibrator Assembly)**
- **Fine Valve**
- **Vent Valve**
- **Rough Valve**
- **Foreline/Reverse Valve**
- **Gross Valve**
- **Sniffer Valve**
- **Purge Valve**
- **Test Port**
- **Test Port Pirani**
- **Vent Filter**
- **Purge Hose Connection**
- **Sniff Hose Connection**
- **Internal Mechanical Pump flex Line**
- **Foreline "flex" Line**
- **Purge Sintered Filter**

Note that the external rough valve, while part of the vacuum system, is not located on the valve block.

Calibrator Valve: A three-way valve that connects the calibrator to the test port. With the use of a filter, this valve is also used to vent the calibrator to atmosphere.

Fine Valve: Connects the test port to the high-vacuum section (mass spectrometer housing). Open during Direct (Fine) Mode testing.

Vent Valve: Connects the test port to atmosphere through a sintered metal filter.

Rough Valve: Connects the inlet port to the internal mechanical pump for initial evacuation of the test object.

Foreline/Reverse Valve: Connects the foreline of the turbomolecular pump to the internal rotary vane mechanical pump and is also used in conjunction with the rough valve for reverse flow testing. This valve is always open on units equipped with an external roughing pump.

Gross Valve: Connects the test port to the foreline of the turbomolecular pump (through a restriction). Open during Gross Mode testing.

Sniffer Valve: Connects the sniffer port to the foreline of the turbomolecular pump. Open during sniff testing.

Purge Valve: Connects the gas ballast port of the internal mechanical pump (through polyflow tubing) to atmosphere through a sintered filter. Can be connected to dry nitrogen. Opening this valve assists in "purging" the system of trapped gases and "condensables" from the pump's oil.

Test Port: A standard KF-25 vacuum connection. Used to attach test objects to the MS-40.

Test Port Pirani: A pressure gauge that monitors the test port pressure from atmosphere to 10^{-3} Torr.

Vent Filter: A sintered metal filter that prevents particles from being drawn into the valve block during venting.

Sniff Hose Connection: 1/4" polyflow tube fitting and tubing. Connects the rear sniff QCF to the sniff valve.

Purge Hose Connection: 1/4" polyflow tube fitting and tubing. Connects the purge valve to the purge fitting on the internal mechanical pump.

Internal Mechanical Pump "Flex" Line: KF16 size stainless steel flex hose. Connects the valve block to the internal mechanical pump.

Foreline "Flex" Line: KF16 size stainless steel flex hose. Connects the valve block to the foreline of the turbomolecular pump.

Purge Sintered Filter: Prevents contaminants from being drawn into the internal mechanical pump through the purge valve.

PUMPS

External Roughing Pump: Optional equipment with the MS-40. A 7 or 16 cfm dual stage rotary vane (mechanical) pump. The pump is capable of reducing pressure from atmosphere to 10^{-3} Torr. Assists in providing a leak test range from 10 to 1×10^{-3} std cc/sec helium. The pump is necessary when testing large objects.

Internal Roughing Pump: A 3 cfm dual stage rotary vane (mechanical) pump. Enables the pumpdown of the test port and test object. Provides "backing" for the turbomolecular pump.

High-Vacuum Pump: A 52 liters/second turbomolecular pump. In fine (direct) mode testing, the pump allows the MS-40 to measure leak rate ranges as low as 4×10^{-11} std cc/sec helium. In this mode, the test port is directly connected to the high-vacuum system.

When performing intermediate (reverse) mode testing, test port gases are channeled to the exhaust area of the turbomolecular pump. The spinning blades of the pump protect the mass spectrometer from these test port gases. Helium molecules however, due to their relatively small mass, are able to "back diffuse" through the blades of the pump. Since heavier gas molecules are trapped by the blades of the pump, only helium enters the high-vacuum system, where the mass spectrometer is able to accurately measure the leak rate.

GAUGES

Test Port Pirani: A gauge that measures pressures from atmosphere to 10^{-3} Torr in the test port.

Foreline Pirani: A gauge that measures pressure at the exhaust of the turbomolecular (high-vacuum) pump.

CALIBRATORS

The MS-40 uses three separate testing modes (gross, intermediate and fine) in order to test leak ranges between 10 std cc/sec to 4×10^{-11} std cc/sec.

Gross Mode: The gross mode calibration covers the range between 10 std cc/sec to 1×10^{-5} std cc/sec. The gross valve has a constriction that allows only a small percentage of the test port gas to enter the high-vacuum section and reach the mass spectrometer. If helium is detected, the signal is amplified (multiplied) by the Gross Mode Gain (G1) to correct the measurement. An external calibrator is required to perform this calibration.

Intermediate and Fine Modes: An internal calibrator that emits helium at a rate between 1×10^{-8} to 3×10^{-8} std cc/sec is standard equipment with every MS-40. External models of differing ranges are also available. Contact Veeco Instruments for further information.

ELECTRONICS

The MS-40's electronics consists of four separate circuit boards (labeled A through D):

- A board** - controls the unit's main processor, logic and sensors
- B board** - controls the unit's mass spectrometer voltage supplies
- C board** - controls the unit's displays and controls
- D board** - controls the unit's handheld remote (optional).

4.3 Calibration & Tuning

The MS-40 may be tuned and calibrated automatically or manually. The automatic (computer assisted) procedures follow:

With the unit in "standby" mode, use the following procedure to calibrate the leak detector:

1. Press the CAL CHECK momentary switch. The unit will begin the "calibration check" sequence.
2. The MS-40's computer will sequence the vacuum system so that:
 - a. the internal leak rate standard is connected to the test port
 - b. the internal calibrator is then measured by the unit
 - c. the background helium is then subtracted from the initial measurement
 - d. the results of the measurement are then displayed on the leak rate bar graph and numeric display of the user panel
3. The indicator on the CAL CHECK switch will now be flashing. This indicates that the measurement has been completed.
4. The alphanumeric display will now indicate the calculated temperature compensated value of the internal leak rate standard. Compare this with the measurement displayed on the leak rate bar graph and numeric display. If the two readings are within 10% of each other, the unit should be considered properly calibrated.

If the difference between the two readings is greater than 10%, the measurement gain may be adjusted by pressing the CAL (Calibrate) button (see below) or the leak detector may be retuned and recalibrated by pressing the TUNE button (again, see below). If the difference between the two readings is acceptable (generally less than 10%) the Cal Check cycle can be ended by pressing the CAL CHECK momentary switch once more.

NOTE

During the warm-up period of the unit (approximately one-half hour), the leak detector's calibration will not be as accurate as during normal operation. When using the MS-40 during warm-up, perform the Cal-Check function to ensure the integrity of the unit's measurement accuracy.

To return to the Standard mode, press the SERVICE pushbutton a second time. The Service Mode indicator will be extinguished and the MS-40 will return to its normal operating mode.

NOTE: After exiting from the Service Mode, the MS-40 requires fifteen seconds to accurately acquire background and other system measurements. During this time, the system computer will prohibit any testing from occurring and the system will "beep" whenever the Start switch is pressed. At the end of this fifteen second time period, a test cycle may be commenced normally by pressing the Start switch.

Another method of checking calibration is a function exclusive to Veeco's MS series of leak detectors: the "Peak Scan" function. Peak Scan allows a user to quickly ascertain whether the leak rate indication is due to either helium or is the result of a poorly tuned spectrometer. To initiate the Peak Scan function:

1. When the unit is leak testing in Standard Mode, press and hold either SELECT momentary switch until the indicator LED for the ANODE VOLTAGE function is lit.
2. Press and hold either the left or right "SET" momentary switch. Pressing the left arrow switch will alter the spectrometer peak tuning voltage by -30 volts while pressing the right arrow switch will alter the voltage by +30 volts. Releasing either switch returns the spectrometer voltage back to normal. When this test is made on an optimally tuned spectrometer, the displayed leak rate (due to either background helium or helium from a calibrator) will decrease to zero indicating that the measurement is actually due to the presence of helium. Both SET buttons should be used for this test.

If the displayed leak rate does not decrease to zero after either SET button is pressed, the spectrometer is not tuned and the TUNE function (see below) must be initiated to retune the mass spectrometer.

To "Tune" the MS-40:

1. When the unit is in Standard Mode, press the TUNE momentary switch (located on the left side of the User Panel).
2. The MS-40 will sequence through a full "Auto Tune" cycle. This includes optimizing all mass spectrometer voltages, finding the optimum voltage, measuring background, adjusting G3 (direct mode) gain and adjusting G2 (reverse mode) gain.
3. When the unit is fully tuned and calibrated, the TUNE indicator light will turn off and the READY LED will be lit.

4.4 Periodic Service

Grease Test Port Centering Ring:

A properly sealing test port O-ring is essential in assuring rapid pump down of a test object. The O-ring should be inspected frequently, at least once each week.

To access the O-ring remove the KF clamp and centering ring atop the test port. With a nonmetallic instrument or by hand, remove the O-ring carefully. Be careful not to nick or damage the O-ring. Once removed, wipe it with a lint free cloth and inspect it carefully for any damage. Specifically, look for any cuts, wear or flat spots. Replace the O-ring if any damage is observed. Whether installing a new or old O-ring, lubricate the O-ring with a thin film of vacuum grease (Dow Corning vacuum grease is recommended). Re-install the O-ring into the test port. Reattach the centering ring and clamp.

Check Air Filters:

The MS-40 has a filter that cleans the cooling air drawn into the unit. The filter is located within the left side panel (as viewed from the front of the unit).

The reusable wire mesh filter can be removed for cleaning by removing the nuts that attach the filters to the outer panel. They may be cleaned with compressed air (in the reverse direction of normal air intake) or can be washed with soap and water.

Check Oil Level in Internal and External Rotary Vane (Mechanical) Pumps

The MS-40 is equipped with either one (internal only) or two (internal and external) pumps depending on its configuration. Each pump has a transparent oil level gauge that allows the user to observe the amount of oil in the pump as well as the oil's coloration.

To observe the oil level, and to access the drain plug and filler port for the internal pump, remove the right side panel (when facing the unit). The level, plug and filler are on the right side of the pump (the pump is illustrated in Figure 1-2). Note that the pump on/off switch is located on the left side of the pump.

Oil should be added to the pump whenever the oil level window indicates that the pump's oil supply is low. If the oil is darker in color than when initially

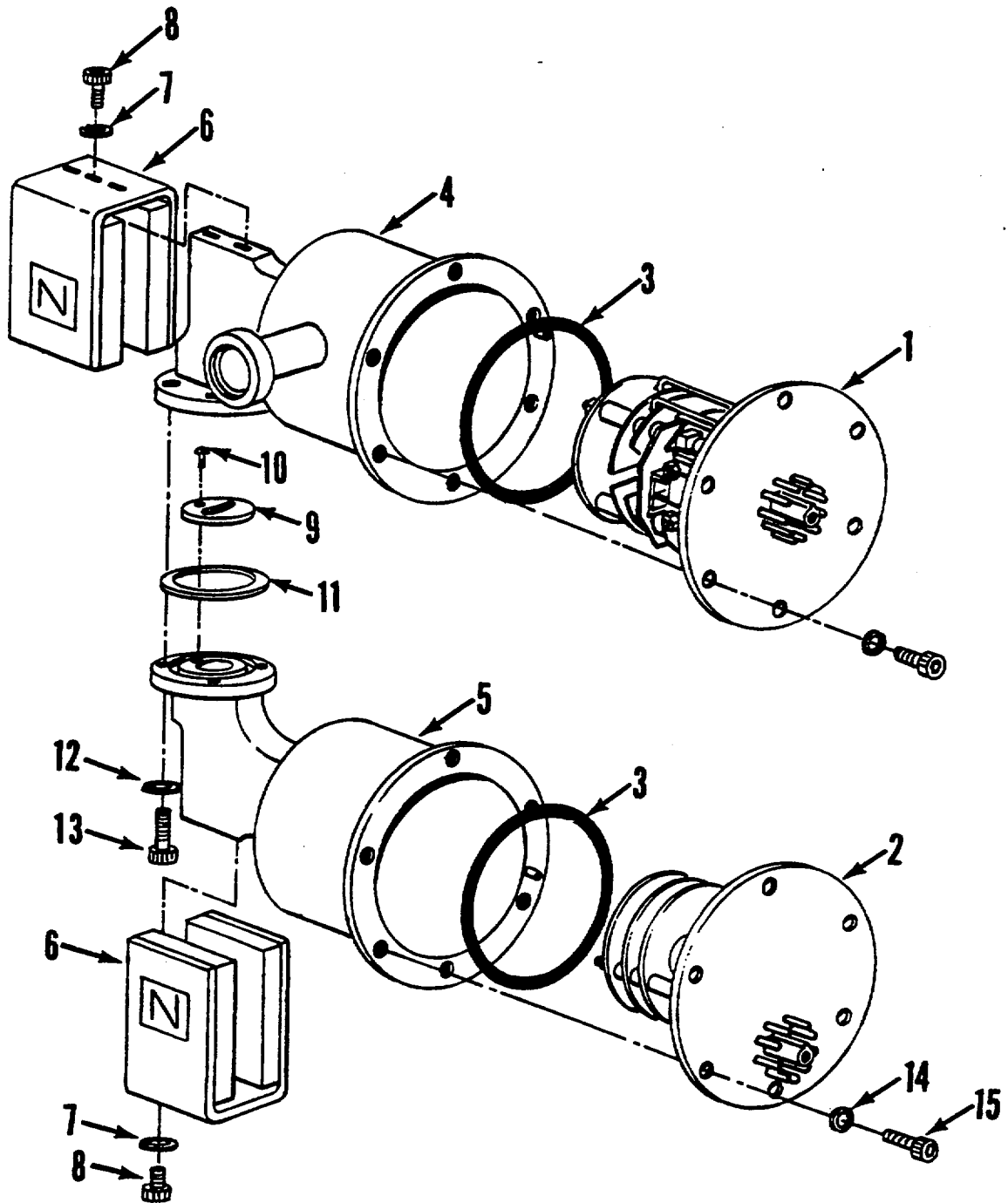


Figure 4-2
MS-40 Mass Spectrometer
(Exploded View)

Parts List for the MS-40 Mass Spectrometer (as illustrated in Figure 4-2):

ITEM #	VEECO P/N	DESCRIPTION
1	0137-014-00	Source Assembly
2	0136-051-00	Collector Assembly
3	0011-037-00	O-Ring, 2 1/2 x 1/16
4	0137-011-00	Source Body
5	0135-053-00	Collector Body
6	0130-151-00	Magnet
7	Commercial	Lockwasher, Split #4
8	Commercial	Screw, #4-40 x 3/8
9	0130-195-00	Slit Plate
10	0130-168-00	Screw, vented, #2-56 x 3/16
11	0011-024-00	O-Ring, 1 1/8 x 1/16
12	Commercial	Lockwasher, Split #6
13	Commercial	Screw, Socket Head, #6-32 x 1/2
14	Commercial	Lockwasher, Split #6
15	Commercial	Screw, Socket Head, #6-32 x 1/2

4.8 Calibration Requirements

Calibration is required when components associated with a measurement function are serviced, repaired or replaced.

The items that need to be calibrated and reset after service, repair or replacement are:

- test port and foreline pirani gauges
- hi-vac gauge
- temperature sensor

Test Port Pirani Calibration

NOTE

Calibration is required whenever a gauge is replaced.

1. Ensure that a blank plug is attached to the test port and that all valves except the foreline valve are closed. Verify that the MS-40 is in the Standard mode.
2. Open the rear panel. To open the rear panel turn the captive screw at the top of the panel 1/4 turn counterclockwise and gently lower the door.
3. Using either of the SELECT arrow keys on the left side of the User Panel, select the Test Port Pressure function. The function has been selected when the green indicator light to its left is lit.
4. Set the unit to manually range downward to 10^{-10} range (to ensure that the unit is in direct mode) by pressing the AUTO/MANUAL momentary switch so that the manual ranging mode is initiated and then pressing the "down arrow" key so that the "10 range" is selected as the eventual "pumpdown" goal.
5. Press the START pushbutton to start the test cycle. Allow the unit to pumpdown so that it reaches Crossover 2. The fine valve will be open (the green indicator next to FINE VALVE on the User Panel will be lit).
6. On the A board mounted on the interior of the rear door, adjust the R101 potentiometer (at the bottom center of the board) so that the

test port pressure is reading one milliTorr on the alphanumeric display. The optimal method is to adjust the potentiometer to slightly greater than one milliTorr, then slowly turn the potentiometer down until the display just indicates 1 mTorr.

NOTE

Be careful not to over-adjust this setting, while the potentiometer can be set to a value less than 1 mTorr, the alphanumeric display will still indicate a reading of 1 mTorr.

Foreline Pirani Calibration

1. Ensure that a blank plug is attached to the test port and that all valves except the foreline valve are closed. Verify that the MS-40 is in the Standard mode.
2. Open the rear panel. To open the rear panel turn the captive screw at the top of the panel 1/4 turn counterclockwise and gently lower the door.

NOTE

The test port pirani must be calibrated prior to calibration of the foreline pirani.

3. Using either of the SELECT arrow keys on the left side of the User Panel, select the TEST PORT (pressure) function. The function has been selected when the green indicator light to its left is lit.
4. Set the unit to manually range downward to a decade that the unit will run in while in reverse mode (e.g., the 10^{-8} range). Make sure not to range down too far (e.g., ranging down to the 10^{-10} range then up to the 10^{-8} range the unit will be in direct mode instead of reverse mode). Wait until test port pressure stabilizes. Record the test port pressure.
5. Using either of the SELECT arrow keys on the left side of the User Panel, select the FORELINE function so that foreline pressure reading appears on the alphanumeric display.
6. On the A board mounted on the interior of the rear door, adjust the R79 potentiometer (at the bottom center of the board) until the

current foreline pressure reading is the same as the test port pressure reading recorded in Step 4.

7. Re-select the TEST PORT function. Verify that the test port pressure is still the same as recorded in Step 4. If the reading has changed, repeat the procedure until the foreline pressure and test port pressure continually match.

Calibrating the Temperature Sensor

1. Ensure that the unit is in standard mode. Open the rear panel. To open the rear panel turn the captive screw at the top of the panel 1/4 turn counterclockwise and gently lower the door.
2. Connect a temperature probe to the temperature sensor located on the body of the internal calibrator.
3. Using either of the SELECT arrow keys on the left side of the User Panel, select the CAL TEMP function so that the temperature reading appears on the alphanumeric display.

NOTE

The temperature probe should have a resolution of 0.1°C .

4. On the A board mounted on the interior of the rear door, adjust the R53 potentiometer (at the bottom right of the board) until the temperature reading of the alphanumeric display matches the temperature indicated by the temperature probe.

4.9 General Service & Repair

Servicing the Valves

The most prevalent cause for a leaky vacuum system is faulty valve closure. A valve's seat and seal become dirty or contaminated with use, causing small leaks that must be corrected for the leak detector to function as required. The valves must be cleaned when a leak develops or the system becomes contaminated as described in Section 4.5. If a valve seal is damaged the valve should be replaced.

Generally, valves exposed to low pressure and high flow are the most likely to be the cause of a leak and should be serviced first. Cleaning procedures are discussed in Section 4.7.

All valve servicing is performed while the unit is in Service Mode. In order to easily access the valve block the rear panel needs to be opened. Refer to Figure 5-2 for an exploded view of the valve block.

CAUTION

Do not use metal tools or sharp objects to inspect a valve seat in the valve block. Any scratch will irreparably damage the seat.

Servicing the Vent Valve

1. Vent the test port.
2. Open the rear panel. To open the rear panel, turn the captive screw at the top of the panel 1/4 turn counterclockwise and gently lower the door.
3. Remove the two wires from the electrical connectors on the valve. Make note of which wire is connected to each metal prong (yellow wire to upper prong/striped wire to lower prong).
4. Remove the four screws and washers. Remove the valve coil.
5. Remove the plunger and the seal assembly from the valve coil. Wipe only the outer area of the seal. Do not remove the seal.

APPENDIX A

Glossary Of Terms Used In Leak Detection

1. **Leak** - In vacuum technology a hole, or porosity, in the wall of an enclosure capable of passing gas from one side of the wall to the other under action of a pressure or concentration differential existing across the wall.
2. **Gross Leak** - A leak which exhibits a leak rate in the range of 10^{-4} to 1 atm cc/sec or higher.
3. **Fine Leak** - A leak which exhibits a leak rate in the range of 10^{-5} to 10^{-11} atm cc/sec or lower.
4. **Leak Rate** - In leak detection practice, leak rate is defined as the rate of flow (in pressure-volume units per unit time) through a leak with gas at a specified high pressure (usually atmospheric pressure) on the inlet side and gas at a pressure on the exit side which is low enough to have negligible effect on the rate of flow.
5. **Leak Detector** - A device for detecting and locating leaks, and indicating the magnitude thereof.
6. **Tracer Gas** - A gas which, passing through a leak, can then be detected by a specific leak detector and thus disclose the presence of a leak. Also called *search gas*.
7. **Probe Gas** - A tracer gas which issues from a more-or-less fine orifice so as to impinge on a restricted test area.
8. **Pressure Testing** - A leak detecting procedure in which tracer gas is introduced under pressure into the enclosure under examination, and detected as it is emitted from a leak.
9. **Soap Bubble Test** - A type of pressure testing in which the tracer gas is detected by bubbles formed in a layer of soap solution applied to the surface of the test object.

10. **Vacuum Testing** - A leak detecting procedure in which the enclosure under examination is evacuated, a tracer gas applied to the outside surface of the enclosure, and the gas detected after entering the enclosure.
11. **Mass Spectrometer Leak Detector** - A mass spectrometer adjusted to respond only to tracer gas. Helium is commonly used as the tracer gas, and thus the instrument is normally referred to as a *helium leak detector*
12. **Spectrometer Tube** - The sensing element of a mass spectrometer leak detector.
13. **Ion Source** - That part of a spectrometer tube in which tracer gas is ionized preliminary to being detected.
14. **Noise Level** - In the case of a leak detector, the spurious output, expressed in suitable terms, exhibited by the detector in the absence of an output due to tracer gas.
15. **Background** - In the case of a leak detector, the spurious output, expressed in suitable terms, due to the response to other gases than the actual gas being used for probing. The background may be inherent in the detector, or accidental.
16. **Minimum Detectable Pressure Change** - The pressure producing an indication of three times the noise level.
17. **Minimum Detectable Leak**
 - a. The size of the smallest leak, expressed in terms of mass flow per unit time that can be unambiguously detected by a leak detector in the presence of noise and background.
 - b. The product of the minimum detectable pressure change and the pumping speed at the detector
18. **Probe Test** - A leak test in which the tracer gas is applied by means of a probe (see below) so that the area covered by the tracer gas is localized. This enables the individual leaks to be located.
19. **Probe** - A tube having a fine opening at one end, used for directing a stream of tracer gas.

20. **Sampling Probe** - A device used in pressure testing and so designed as to collect tracer gas from a restricted area of the test object and feed it to the leak detector. Also called *pressure probe* or *sniffer*.
21. **Hood Test** - An overall test in which an object under vacuum test is enclosed by a "hood" which is filled with tracer gas so as to subject all parts of the test object to examination at one time.
22. **Isolation Test** - A method of determining whether a leak is present in a system, or of obtaining an estimate of its magnitude, by observing the rate of rise of pressure in the evacuated system when the system is isolated from the pump. Also called *rate of rise* test.
23. **Masking** - The covering of a section of a test object so as to prevent tracer gas from entering leaks that may exist in the covered section.
24. **Flooded System** - A system which, while being leak tested under vacuum, becomes so filled with tracer gas as to make impracticable further leak detection by means of a probe.
25. **Helium Drift** - In the case of leak detection with a helium probe, the drift of helium to a leak or permeable gasket located at a point sufficiently remote from the end of the probe to mislead the operator into suspecting the area near the probe.
26. **Standard Leak**
 - a. A device which permits leakage through it, at a specified rate, of a specified gas, with atmospheric pressure at one end of the device and a pressure on the other side sufficiently low to have negligible effect on the leak rate.
 - b. A capillary or porous wall leak, usually in a glass or metal tube, whose dimensions have been adjusted to give a conductance within specified limits for a specified gas at a standard reference temperature with specified inlet and exit pressures. Standard leaks for attaching to vacuum test manifolds with air at atmospheric pressure exposed to the inlet are usually protected by filters to avoid clogging by dust particles. Standard leaks for calibrating mass spectrometers are usually fused to a glass reservoir containing the specified gas at a known high pressure.
 - c. A device providing a known throughput into a vacuum system. Also referred to as a *calibrated leak*.

APPENDIX B

A.V.S. Standards

Standards of the American Vacuum Society for the Testing of Mass Spectrometer Leak Detectors

The following paragraphs are extracted, with permission of the American Vacuum Society, from AVS Standards used in defining and testing the operation of mass spectrometer leak detectors. They have been selected because of their application in the testing of all Veeco leak detectors. Copies of complete AVS Standard 2.1 ("Calibration of Leak Detectors of the Mass Spectrometer Type") and AVS Standard 2.3 ("Procedure for the Calibration of Gas Analyzers of the Mass Spectrometry Type") are available by writing to Veeco Instruments, Inc.

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AVS Standard 2.1

3.1 BACKGROUND

3.1.1 General

In general, background is the total spurious indication given by the leak detector without injected search gas. Background can originate in either the mass spectrometer tube or the associated electric and electronic circuitry, or both. (Frequently, the term is used to refer specifically to the indication due to ions other than those produced from injected search gas).

3.1.2 Drift

The relatively slow change in the background. The significant parameter is the maximum drift measured in a specified period of time.

3.1.3 Noise

The relatively rapid changes in the background. The significant parameter is the noise measured in a specified period of time.

3.1.4 Helium Background

Background due to helium released from the walls of the leak detector or leak detection system.

3.4 LEAKS

3.4.1 Leak (n)

In vacuum technology a hole, porosity, permeable element, or other structure in the wall of an enclosure capable of passing gas from one side of the wall to the other under action of a pressure or concentration difference existing across the wall.

Also, a device which can be used to introduce gas into an evacuated system.

3.4.1.1 Channel Leak

A leak which consists of one or more discrete passages that may be ideally treated as long capillaries.

3.4.1.2 Membrane Leak

A leak which permits gas flow by permeation of the gas through a nonporous wall. For helium, this may be a wall of glass, quartz, or other suitable material.

3.4.1.3 Molecular Leak

A leak through which the mass rate of flow is substantially proportional to the reciprocal of the square root of the molecular weight of the flowing gas.

3.4.1.4 Viscous Leak

A leak through which the mass rate of flow is substantially proportional to the reciprocal of the viscosity of the flowing gas.

3.4.2 Calibrated Leak

A calibrated leak for which the rate of leakage is known under standard conditions, namely, $23 \pm 3^\circ\text{C}$, a pressure of 760 Torr $\pm 5\%$ at one end of the leak, and a pressure at the other end so low as to have a negligible effect on the leak rate.

3.4.3 Virtual Leak

The semblance of a leak due to the evolution of a gas or vapor within a system.

3.5 LEAK RATES

3.5.1 Leak Rate

The mass rate (also called "throughput"; differentiated from volume rate of flow (liters/sec) also called pumping speed), in Torr liters/sec (or Pa m³/sec) at which a specified gas passes through a leak under specific conditions.

3.5.2 Standard Air Leak Rate

The mass rate of flow, through a leak, of atmospheric air of dew point less than -25°C under standard conditions specified as follows: the inlet pressure shall be less than 760 Torr $\pm 5\%$, the outlet pressure shall be less than 10 Torr and the temperature shall be 23 ± 3 °C.

3.5.3 Equivalent Standard Air Leak Rate

Short path leaks having standard air leak rates less than 10⁻⁶-10⁻⁷ Torr liters/sec (10⁻⁷-10⁻⁸ Pa m³/sec) are of the molecular type (see Sec 3.4.1.3). Consequently, helium (mol. wt 4) passes through such leaks more rapidly than air (mol. wt 29) and a given flow rate of helium corresponds to a smaller flow rate of air. In this recommendation, helium flow is measured and the "equivalent standard air leak rate" is taken as $(4/29)^{1/2} = 0.37$ times the helium leak rate under standard conditions (see Sec 3.5.2).

3.8 SENSITIVITY TERMS

3.8.1 Sensitivity

The sensitivity of a device is the change in output of the device divided by the change in input which caused the response.

3.8.2 Minimum Detectable Signal

An output signal due to incoming search gas which is equal in magnitude to the sum of the noise and the drift.

3.8.3 Minimum Detectable Leak (or Minimum Detectable Leak Rate)

The smallest leak, as specified by its standard air leak rate, that can be detected unambiguously by a given leak detector. The minimum

detectable leak rate depends on a number of factors. One of the purposes of this Standard is to describe practical procedures for determining minimum detectable leak rate, taking into account background, volume rate of flow (pumping speed), and time factor.

3.8.4 Minimum Detectable Concentration Ratio

The smallest concentration ratio of a given search gas in an air mixture that can be detected unambiguously by a given leak detector when the mixture is fed to the detector at such a rate as to raise the pressure in the instrument to some optimum high value. In this Standard, the minimum detectable leak rate is calculated by a somewhat arbitrary procedure from observations of the response of leak detector to a helium-air mixture of known helium concentration ratio.

5 Test Procedure Minimum Detectable Leak

5.1 DRIFT AND NOISE OBSERVATION

5.1.1

The output of the leak detector is connected to the recorder, the leak detector being at its maximum sensitivity setting and the inlet valve closed.

5.1.2

The leak detector backing-off (or zero) control is adjusted so that the recorder reading is approximately 50% of full scale, the filament being on.

5.1.3

The output is recorded for 20 min. or until the output has reached full scale, for positive drift, or zero, for negative drift.

5.1.4

Draw a series of line segments intersecting the curve recorded in Sec. 5.1.3, the lines to be drawn at 1-min. intervals at right angles to the time axis (abscissa) of the chart, and to commence at the point where the procedure of Sec. 5.1.3 is started. The lines so drawn will be called the "1-min lines."

Draw straight-line approximations for each segment of the curve between adjacent 1-min lines.

5.2 DRIFT AND NOISE DETERMINATION

5.2.1

Examine the straight line approximations of Sec. 5.1.4 to determine that 1-min segment of the output curve having the greatest slope. This greatest slope is measured in scale divisions per minute and is called the drift. If the greatest slope is less than the scale divisions corresponding to 2% of full scale of the recorder, the total (absolute) change in output over the 20-min period is determined. The total change is divided by 20 is then called the drift.

5.2.2

For each 1-min segment of the curve, determine the maximum (absolute) deviation of the recorded curve from the straight-line approximation.

5.2.3

The average of these maximum deviations, multiplied by 2, is called the noise (scale divisions).

Note: In determining the noise, neglect any large deviation (spike) which occurs less frequently than once in any 5-min interval.

5.3 MINIMUM DETECTABLE SIGNAL

The minimum detectable signal is taken to be equal to the sum of the absolute values of the drift and of the noise. It should be measured in scale divisions. If the sum is less than the scale divisions corresponding to 2% of full scale, then the scale divisions corresponding to 2% of full scale is called the minimum detectable signal.

5.4 SENSITIVITY DETERMINATION

5.4.1 Arrangement of Apparatus

The leak detector is connected to an auxiliary system. (Frequently, the auxiliary system is included with the leak detector as an integral part thereof).

The system should contain a minimum of rubber or other polymeric surfaces. Preferably, such surfaces should consist only of the exposed surfaces of an O-ring or O-rings. Accordingly, the "Leak Isolation Valve"

should preferably be of all-metal construction, but in any case should not act as a significant source of adsorbed or absorbed helium.

5.4.2 Spurious Signal Correction

Note: This determination requires the use of the small calibrated leak. If the calibrated leak has its own integral valve, and the leak and valve are all-metal construction (except perhaps for the membrane in a membrane-type leak), Sec. 5.4.2 may be omitted from the procedure.

5.4.2.1

A metal plug is connected to the leak detector

5.4.2.2

The output is zeroed, with the filament on.

5.4.2.3

The leak isolation valve is opened.

5.4.2.4

The pump valve is opened. (*Note: For its safety, the filament of the mass spectrometer tube may be turned off at this point*).

5.4.2.5

When the atmospheric air present between the plug and the inlet valve has been evacuated, the pump valve is closed.

5.4.2.6

The inlet valve is opened promptly, but gradually. The pressure in the leak detector is allowed to reach a steady value, showing no observable change in a 1-min period.

5.4.2.7

Turn on filament of mass spectrometer tube if it is not on.

5.4.2.8

When the output has reached a steady value, but in any case not longer than 3 min after Sec. 5.4.2.6. the output reading is noted. If the leak detector has been set at reduced sensitivity, the reading should be converted to equivalent scale divisions for full-sensitivity setting.

5.4.2.9

Close the leak isolation valve as rapidly as feasible.

5.4.2.10

Note the output reading 10 seconds after closing the isolation valve. As in 5.4.2.8., convert the reading if necessary.

5.4.2.11

Subtract the reading noted in 5.4.2.10 from that noted in 5.4.2.8. If the difference is negative, it is to be considered equal to zero. The difference will be called the "spurious-signal correction" and will be applied in Sec. 5.4.3.14.

5.4.2.12

Close the inlet valve.

5.4.2.13

Open the vent valve.

5.4.2.14

Remove only the plug from the inlet line; all connections are to remain in place.

5.4.2.15

Close the vent valve.

5.4.3 SENSITIVITY

5.4.3.1

Connect the all-metal leak to the leak detector. However, if the procedure of 5.4.2. was necessary, the small calibrated leak is put in place of the plug removed in 5.4.2.14 above, the leak being inserted the same distance into the connection as the plug had been.

5.4.3.2

The output is zeroed with the filament on.

5.4.3.3

The leak isolation valve is opened.

5.4.3.4

The pump valve is opened.

5.4.3.5

Helium at 760 Torr $\pm 5\%$ pressure is applied to the leak. If the leak has its own supply of helium, this step is omitted. (*Note: the filament of the mass spectrometer tube may be turned off before Sec. 5.4.3.6.*)

5.4.3.6

When the atmospheric air present between the calibrated leak and the leak detector has been evacuated, the pump valve is closed.

5.4.3.7

The inlet valve is opened promptly after Sec. 5.4.3.6. The pressure in the leak detector is allowed to reach a steady value, showing no observable change in 1 min.

5.4.3.8

Turn on filament of mass spectrometer tube if it is not on.

5.4.3.9

At this point it may be necessary to change the sensitivity setting. When the output signal has reached a steady value, showing a change in 1 min which is not greater than the drift (as corrected for the sensitivity setting), the output reading in scale divisions is noted. If the leak detector has been set at reduced sensitivity, the reading should be converted to the equivalent scale divisions for full-sensitivity setting.

5.4.3.10

Immediately after the proceeding step, the stopwatch is started and simultaneously the leak isolation valve is closed as rapidly as practical. Alternatively, the recorder chart may be marked to indicate the beginning of the timed period and the leak isolation valve then closed rapidly.

5.4.3.11

The output is observed continuously and the stopwatch is stopped when the reading has decreased to 37% of the reading observed in Sec. 5.4.3.9. The reading of the stopwatch is noted (T sec.). Alternatively, the recorder chart is examined to determine the time T required for the specific decrease in output. T is the response time (Sec. 3.9.2).

Note: Should response time be a function of sensitivity setting, T as observed should be corrected to response time at full sensitivity setting, if any other setting was used.

5.4.3.12

One minute after closing the leak valve (see Sec. 5.4.3.10), the output is read and noted. Correct for sensitivity setting as in 5.4.3.9.

5.4.3.13

The uncorrected signal due to the calibrated leak shall be taken as the difference between the reading noted in 5.4.3.9, and that noted in 5.4.3.12, the required conversion of these readings to equivalent scale divisions at full-sensitivity setting have been made.

5.4.3.14

The corrected signal due to the calibrated leak is taken as the difference between the uncorrected signal, Sec. 5.4.3.13, and the spurious signal correction in 5.4.2.11. The sensitivity is calculated by the formula below and should always be stated together with the response time, T:

The units are scale divisions (on full sensitivity setting) per unit leak rate (Secs. 3.5 and 3.8).

Sensitivity, with Response Time, T =

Signal due to Calibrated Leak

**Standard or Equivalent Standard Air Leak Rate of
Calibrated Leak**

5.5 MINIMUM DETECTABLE LEAK

Referring to Secs. 5.3 and 5.4.3.14, this is calculated from the formula
Minimum Detectable Leak, with Response Time T =

Minimum Detectable Signal

Sensitivity

The units are those of leak rate.

AVS Standard 2.3

2.3 SCANS

A scan is usually shown as a trace on a recorder chart, the abscissa is time, mass, voltage, gauss, etc., and the ordinate is assumed proportional to ion current or "output". It can also be shown as a table of values, an oscilloscope trace, etc. (The term "mass spectrum" is synonymous with scan or mass scan.) In this standard, it will be assumed for sake of simplicity that the scan is a recorder trace (see Sec. 7.4 "Recorder"), and that the recorder displacements are proportional to input currents.

3.11 PEAK WIDTH, W

In a graphical spectrum, the length of the base of a peak, the base being defined by the intersection or tangency of the legs of the peak with a reference base line. The specification of such a reference line is an important function of this standard. In some discussions, the symbol Δm or ΔM is used for peak width rather than W . The units of W are atomic mass units; in some cases, a conversion of units may be necessary (see 2.3 and 4.1).

3.16 RESOLUTION

3.16.1 General Definition

The ability, or a measure of the ability, of a mass spectrometer to separate the peaks produced by ions of different mass/charge ratios.

3.16.2 Absolute Resolution. (*See General Definition above*).

A measure of the ion-separating ability of a mass spectrometer, at a given mass M , given by the peak width, W , at M :

$$\text{Absolute resolution (at } M) = W \text{ amu}$$

3.16.3 Unity Resolution Mass(es).

The mass number(s) at which the absolute resolution is one (amu) or "unity".

3.16.4 Resolving Power.

At a given mass M , the ratio of M to peak width W :

$$\text{Resolving Power} = \frac{M}{W} = \frac{M}{M} \quad (\text{see 3.11})$$

4 Discussion of Resolution

4.1 MASS SCALE

Some mass spectrometers produce a graphical scan having an abscissa which is not linear in mass number. It then becomes necessary, for the calculation of resolution, to convert the abscissa to a linear mass scale. To do this, it is assumed that, for a *sufficiently small* range of mass numbers, the abscissa is actually *linear* in mass number. To convert from the abscissa scale to mass units, the following formula is used:

$$L = \frac{S'}{M_1 - M_2} = \frac{S'}{\Delta M}$$

where:

S = peak separation in any convenient units (centimeters, volts, cycles per second, etc.)

L = the number of units, of the kind chosen for S , equivalent to 1 mass unit

M_1 = mass of peak at which resolution is to be determined

M_2 = mass of a neighboring peak $\Delta M = M_1 - M_2$

Then, if W' is the peak width in the same units as those of S' ,

$$\begin{aligned} \text{Absolute Resolution} &= \frac{W'}{L} \quad (\text{by definition}) \\ &= M \times W / S \end{aligned}$$

7.4 RECORDER

This standard requires that the output of the gas analyzer being tested be graphically presented by means of chart recorder. The recorder shall be an instrument which traces a continuous line and which has a time constant (63%) not greater than one second. The recorder shall be so buffered that there is no interaction between the recorder and the meter or other output-indicating device of the gas analyzer; i.e., so that the velocity of response of neither generates sufficient electrical signal to affect the indication of the other. If the recorder is connected in parallel with the output indicator, this interaction will become negligible if each has an input resistance 1000 times that of their common voltage source, or if the recorder draws 1/1000 as much current as the indicator.

While some recorders have automatic decade-switching capabilities, it will be assumed that this recorder can cover only a single linear range; it is also assumed that the recorder displacement is proportional to the input current. In those cases where the analyzer has an output meter, controls shall be available which permit adjusting the zero of the recorder to the zero of the meter, and full-scale deflection of the recorder to full-scale deflection of the meter. This is necessary to permit direct correlation of the meter and recorder indications and also to prevent possible injury to one or more of these devices. However, in order to prevent complications in the language of this standard, it will be assumed that the recorder is the only output indicating device, and that controls for adjusting zero indication and for attenuating output indication act directly on the recorder.

ATTACHMENT 5

CHANGED PAGES FOR REVISION 2 OF THE SAR FOR THE MODEL ESP-30X PROTECTIVE SHIPPING PACKAGE FOR 30- INCH CYLINDERS

Please replace each of the attached amended pages in each of the ten SAR (ten copies attached). Each page is marked with two vertical lines in the right margin next to the modified sentences, to indicate the second revision. The amended pages are further described as follows:

Cover Page: Added "Revision 2" and updated address

Title Page: Added "Revision 2" and changed date

Page 1-4 and Page 1-5: Revised Section 1.2.3 "Contents of Packaging" to correct isotopic concentrations so that they are consistent with those listed in the containment section. Also, restored the total quantity of contaminants present in the package discussion.

Sherwin Williams Product Data - Please insert this specification at the end of Appendix 2.10.2 and Appendix 2.10.9 to clarify the paint coating used on the carbon steel surfaces in contact with the foam.

Southwest Research Institute ERRATA dated March 13, 2000 and Southwest Research Institute (SWRI) ERRATA dated July 20, 1999 - Please insert both of these letters at the beginning of Appendix 2.10.9 as a response to NRC questions regarding SWRI's performance evaluation of the Model No. ESP-30X under hypothetical accident conditions.

Page 4-1 thru 4-3: Revised 30B external design pressure to 25 psig, revised Section 4.2.1 "Containment of Radioactive Material", Section 4.2.3 "Containment Criterion", and Section 4.3.2 "Containment of Radioactive Material" to be more concise and accurate.

Appendix 4.4.1: Added "Leakage of Contents to Environment" Heading and added "Inleakage of Water" paragraph

Appendix 4.4.2: Added "Leakage of Contents to Environment" Heading and added "Inleakage of Water" paragraph

Page 7-1: Section 7.1.3 "Additional Type B Requirements for Cylinder Inspection" (b) changed A2 value; (c) changed leak rate.

Page 8-1: Section 8.1.3 "Type B Acceptance Test for the 30B Cylinder" changed leak rate.

Page 8-4: Section 8.2.3 "Type B Inspection for the 30B Cylinder" (b) changed A2 value; Section 8.2.3.2 "Annually" changed leak rate.

**Safety Analysis Report for the
Model ESP-30X Protective Shipping Package
for 30-inch UF₆ Cylinders**

Revision 2

Submitted by



Columbiana, Ohio 44408

ATTACHMENT 5

**CHANGED PAGES FOR REVISION 2 OF THE SAR FOR THE
MODEL ESP-30X PROTECTIVE SHIPPING PACKAGE FOR
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